LESS-ALTERED CI LITHOLOGY IN THE KAIDUN METEORITE BRECCIA. Michael Zolensky[1], Karen Ziegler[2], Loan Le[3], Takashi Mikouchi[4], Minami Masuda[4], Kenei Ogiya[4]. [1]ARES, NASA Johnson Space Center, Houston, TX 77058 USA (michael.e.zolensky@nasa.gov); [2]Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131 USA; [3]Jacobs, Houston, TX 77058 USA; [4]University of Tokyo, Tokyo, Japan.

Introduction: One of the most interesting initial results of the characterization of the asteroid Ryugu regolith material returned by the Hayabusa2 spacecraft is the presence of a significant quantity of less-aqueously altered CI material, tentatively called "CI2" [1]. This lithology is characterized by an approximately ten-fold increase in the amount of anhydrous ferromagnesian silicates over what is found in CI1 chondrites, with these being principally olivine, low- and high-calcium pyroxene. Remnant CAI phases are found as well as probable chondrule fragments. Magnetite, pyrrhotite and hydroxyapatite are abundant. The main carbonate is calcite. Matrix is mainly a mixture of saponite and serpentine phases. Assuming that this lithology should be a better representative of the more "primordial" mineralogy of early nebular solids than more processed CI1 material, we have been re-examining CI lithologies found as separate meteorites as well as clasts in other meteorites, seeking similar CI2 material. The Kaidun breccia is notorious for including almost every type of meteorite class except CR2 (which is ironic considering that Kaidun is still officially classified as CR2 [2]). We report here the discovery of a probable CI2 lithology in one carbonaceous chondrite-rich Kaidun sample.

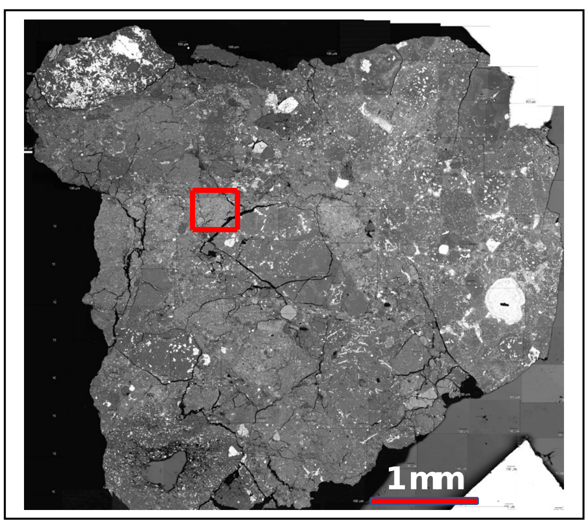


Figure 1. BSE image of PTS 3. The red box indicates the location of the CI2 lithology.

Techniques: All E-beam work was performed at ARES (NASA JSC) labs. SEM work was performed using a JEOL 7600 FEG SEM with an Oxford Instruments Ultimax Silicon Drift Detector (SDD) spectrometer. Mineral compositions were measured using a JEOL JXA-8530F field emission EMPA equipped with a ThermoScientific EDS system. O isotope measurements mentioned here were described previously [3].

Kaidun PTS 3. One of the first Kaidun thin sections we made together with the late Andrei Ivanov of the Vernadsky Institute back in the late 1980s was PTS 3. This particular sample is dominated by diverse C1 and C2 carbonaceous chondrite lithologies, in addition to other materials including igneous clasts and enstatite chondrites [3]. CI1 and CM2 classifications for many lithologies in this particular sample were verified by O isotope measurements reported previously [3]. The dominant C1 lithology in this sample is thus known to be CI1 as revealed by the bulk O isotope composition which is $\delta^{17}O$=7.745 to 8.741, $\delta^{18}O$=12.816 to 16.198 [3]. In most respects the CI1 lithologies in Kaidun are identical to those reported as meteorites and the bulk of the Ryugu materials. A BSE mosaic of section PTS 3 is shown in Figure 1.

CI2 Lithology: The apparent CI2 lithology in Kaidun is in most respects identical to the CI1 lithology, being dominated by a mixture of saponite and serpentine (Figs. 2,3). Magnetite is abundant, including framboids, plaquettes, spherules and euhedral crystals.

Pyrrhotite, pentlandite, and Ca phosphates are abundant. Calcite is common, both in well-formed crystals and as grains with very irregular outlines, suggesting partial dissolution (Fig. 2d). Dolomite was not observed. The abundance of olivine, low - and high-Ca pyroxene is much higher than we have observed in CI1 meteorites (Fig. 2). The range of compositions of the olivine and low-Ca pyroxene is still being assessed, but is quite wide, as is observed in CI1 chondrites [4]. One kamacite grain is present in a relict forsterite grain (Fig. 2d), which is typical of C2 chondrites.

The phyllosilicates in Kaidun CI1 and CI2 were measured together by EPMA (this was done before we recognized the different lithologies), and Figure 3 shows that these measurements are consistent with analyzed phyllosilicates in CI1 meteorites and the Ryugu CI1 and CI2 lithologies. The Kaidun phyllosilicates are more homogeneous than the other CI2s with respect to the plotted elements, which is not completely understood.

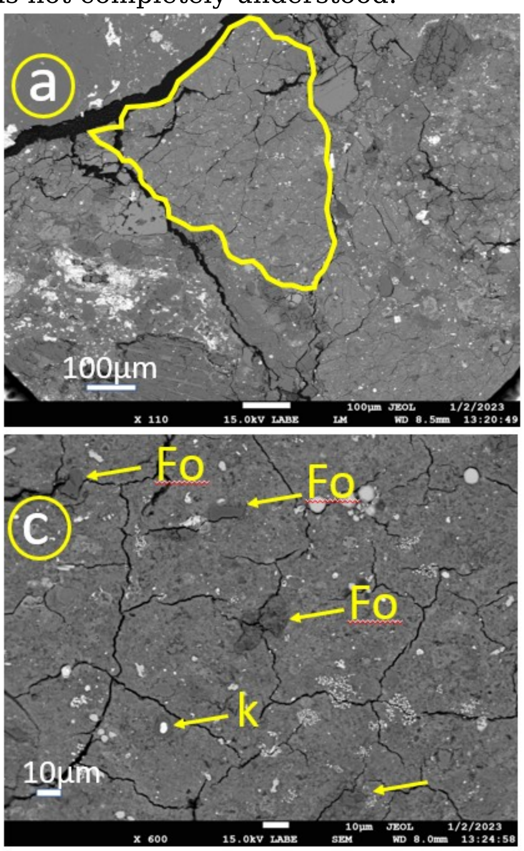
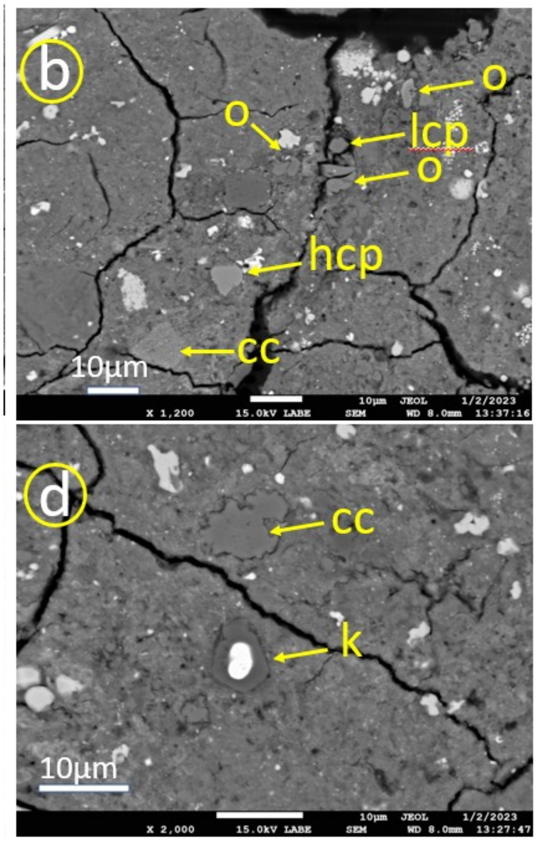


Figure 2. BSE images of the CI2 lithology in Kaidun. (a) Yellow form encloses the CI2 lithology. (b-d) Higher magnification images. Fo is forsterite, O is olivine, lcp is low-Ca pyroxene, hcp is high-Ca pyroxene, cc is calcite, k is kamacite within a forsterite grain. Other white grains are magnetite or pyrrhotite.

All phyllosilicates in CI chondrites are a mixture of saponite and serpentine phases, as has been known for decades [1]. The presence of the same phyllosilicates in both CI2 and CI1 chondrites suggests limited change in solution chemistry during aqueous alteration, however the measured CI2 material from Kaidun has a more homogeneous compositional range. This may be due to the more limited sample size.

Implications: It is likely that this material is fairly widespread among CI samples, though in small relative abundance. Endreß first noted its presence in 1995 [5]. CI2 material provides a view of the precursor mineralogy of compositionally primitive CI chondrites.

References: [1] Nakamura et al (2022) *Science* **377**, 10.1126/science.abn8671; [2] Zolensky and Ivanov (2003) *Chemie de Erde* **63**, 185-246; [3] Ziegler et al. (2012) *43rd LPSC*, Abstract XXXXI; [4] Frank et al. (2014) *GCA* **126**, 284–306, [5] Endreß M. (1995) Ph.D. thesis, University of Münster.



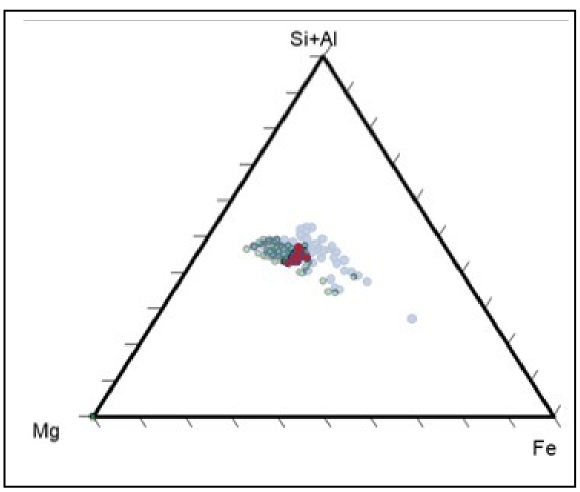


Figure 3. Bulk composition of phyllosilicates in the Kaidun CI1 and CI2 lithology (red) compared to those of CI1 chondrites (light blue) and Ryugu samples (green, both CI1 and CI2) (from [1]). The compositions are shown plotted onto an atom% triangular plot. The Ryugu phyllosilicates tend to be slightly enriched in Mg relative to CI1 meteorites, and the Kaidun phyllosilicates are more homogeneous than the other materials.